Assessment of Mercury in Edible Fish Fillets at Seney National Wildlife Refuge

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Background

This report is a follow-up to work conducted by the East Lansing Field Office (ELFO) at Seney National Wildlife Refuge (NWR) in 1987-88 to assess the presence and degree of contamination in soils and biota due to historic onsite management activities (Best *et al.* 1995). While the onsite activities were found not to have impacted biota, fish collected from several ponds on the refuge were found to have elevated levels of mercury (Hg) in whole fish and skinless fillets. Levels of Hg in the larger northern pike (*Esox lucius*) exceeded State and Federal criteria for human consumption and interstate trade, respectively (>0.5 and >1.0 *ug/g* Hg, wet weight, respectively). The sources of the Hg are unknown but may be attributable to aerial transport and deposition from combustion processes at industrial facilities within and outside the Great Lakes basin. Degradation of parent soils and bedrock may also be a local source of Hg. However, the 1987-88 data for Hg in fish were compromised by poor Quality Assurance/Quality Control (QA/QC) practices by the laboratory contracted by the Patuxent Analytical Control Facility (PACF), U.S. Fish & Wildlife Service. PACF reanalyzed a subset of the samples and confirmed the elevated levels of Hg in the fish. Due to the poor QA/QC practices by the contract laboratory and the limited sample size, ELFO concluded it would be premature to recommend altering the management direction at Seney NWR regarding access and consumption of fish by humans and wildlife. ELFO recommended that additional fish collections be undertaken for Hg analysis in the future. ELFO further recommended that if Hg continues to be a problem, then an expanded long term assessment of Hg in fish be implemented. The present report documents the results of this expanded sampling effort as it relates to human consumption of fish from Seney NWR. The risks to fish-eating wildlife will be addressed in a separate report.

In 1989 the Michigan Department of Community Health (MDCH) issued a special consumption advisory for Hg in fish for all inland lakes in the State. This was based on the collection and analysis of fish of various species from about 200 lakes statewide. The advisory applies to all inland lakes regardless of whether they were sampled. The only lakes exempted from the advisory were those sampled lakes where fish did not exceed the criteria. No pools or streams were sampled within Seney NWR. Therefore, the special consumption advisory for Hg in fish from inland lakes applies to Seney NWR. The general advisory for inland lakes applies to rock bass (*Ambloplites rupestris*), yellow perch (*Perca flavescens*), or crappie (*Pomoxis* sp.) over 228.6 mm (9 in) in length, or bass (*Micropterus dolomieui* and *M. salmoides*), walleye (*Stizostedion vitreum*), northern pike, or muskellunge (*Esox masquinongy*) of any size. Of these fish covered under the general advisory, the northern pike, yellow perch and black crappie (*P. nigromaculatus)* are known to occur in refuge pools. Walleye and smallmouth bass are known to occur in the Manistique River and may be found in the reach of the river within Seney NWR.

In 1998 the criteria for placing fish on the advisory were changed by the MDCH from those used in previous years. For fish exceeding 1.5 *ug*/g Hg, wet weight (wet wt.), no consumption of fish is advised. For fish in the range of 0.5-1.5 *ug*/g Hg, wet wt., a limited consumption of one meal per week is advised for the general population, and one meal per month is advised for pregnant women, nursing mothers, women who plan to have children, and children under 15 years of age.

The MDCH has also issued specific consumption advice for Hg in the Manistique River upstream of the dam in Manistique. This includes the section of the river within Seney NWR. For northern pike greater than 558.8 mm (22 in) in length, a limited consumption of one meal per week is advised for the general population, and one meal per month is advised for pregnant women, nursing mothers, women who plan to have children, and children under 15 years of age. No advisory is issued for northern pike less than 558.8 mm in length.

Information on the consumption advice for Hg in Michigan fish may be obtained from the MDCH's website at: www.mdch.state.mi.us/pha/fish/mercury.htm.

The U.S. Food and Drug Administration (USFDA) has established a Tolerance Level for Hg in fish for interstate commerce at 1.0 *ug*/g, wet wt.

Fish consumption is also controlled through the setting of minimum sizes for hook and line sport fishing. The Michigan Department of Natural Resources, Fisheries Division has set a minimum size for northern pike at 609.6 mm in length (24 in) statewide. However, under special regulations and exemptions, Seney NWR has no size limits for northern pike taken from its pools. In addition, no State limits on minimum size are set for yellow perch, white sucker (*Catostomus commersoni*) and pumpkinseed (*Lepomis gibbosus*) statewide, the other species addressed in this report.

Portions of Seney NWR are open to public access for sport fishing. Pools C3, E, F, G, H, I and J are open for fishing from May 15-September 30, while Pools C1 and D are open only during the month of September (Figure 1). In addition, the portions of the Manistique River, Driggs River, Creighton River, and Walsh Creek and Ditch on the Seney NWR are also open to fishing during regular state seasons.

Methods

Field Collections

Fish were collected in 1996 and 1997 from 12 managed pools within Seney NWR (Figure 1). In 1996, staff from the Ashland Fisheries Resources Office (FRO) and the Green Bay FRO collected 17 fish from J and G pools on the nights of July 17-18 using an 18-foot electrofishing boat (600 volts DC at 2 amps). In 1997, staff from the Green Bay FRO collected 70 fish from C3, D, and Marsh Creek pools on July 22-24 and from A1, A2, and H

pools on August 18-19 using an 18-foot electrofishing boat (400-600 volts DC at 3-4 amps). Most collections were made at night during the regularly scheduled fishery assessments of these pools. A single pass was made along the shoreline of each pool and all stunned fish were collected. However, collections from D and A2 pools were made during the day expressly for the purpose of collecting contaminant samples for this project, so only certain species and sizes were targeted. These collections were supplemented by Seney NWR staff who collected 38 fish from A1, A2, C2, D, G, I and Marsh Creek Pools, and from the Riverside Dike Pools along Driggs River using hook and line and gill nets in the period of June 4-13, 1997.

After capture, fish collected using electrofishing were measured to the nearest mm, weighed to the nearest gram, and scales removed from those fish greater than 100 mm for later aging. Fish collected using hook and line and gill nets were measured to the nearest inch. Each fish was individually wrapped in aluminum foil, labeled, placed in a plastic bag, prior to freezing at Seney NWR. Fish were later transferred frozen to ELFO for sample preparation and processing.

Sample Preparation and Processing

A total of 125 fish from four species were processed by ELFO for analysis. Since weight and length measurements were not consistently taken during field collections, each fish was again measured in the laboratory. Each fish was thawed, and measured for total body length (to the nearest 5 mm) and whole fish weight. Lengths and weights from frozen specimens are known to be altered from similar measurements from fresh specimens. At least one scale was removed from the side of the fish and archived for possible future aging. To evaluate two routes of exposure, paired fillet samples were prepared from each fish; one fillet with the skin-off and the other with the skin-on. Since Hg predominantly resides in muscle tissue within the body, the removal of the skin from a fillet should constitute the worst case scenario of human exposure to Hg via consumption. Each fillet sample was weighed, wrapped in aluminum foil, labeled, placed in a plastic bag and refrozen. A total of 250 samples were shipped via overnight express delivery to PACF for analysis.

Analytical Chemistry

All samples were analyzed by PACF for Hg using the cold vapor atomic absorption method (Monk 1961) with the results reported to three significant digits. The nominal lower limit of detection was 0.05 *ug*/g Hg, wet wt. In addition, percent moisture was determined for each sample to permit reporting of the results by PACF on both a wet and dry weight basis. QA/QC was monitored through the analysis of duplicate samples, procedural blanks, spiked sample recoveries, and standard reference material samples (dogfish liver). Based on the QA/QC program, PACF identified the following three anomalies:

1. The relative percent difference for one of the 19 Hg duplicates was slightly higher than is normally seen,
2. The recovery of Hg from one of 19 spiked samples was slightly higher than normally seen, and

3. The recovery of Hg from one of 19 reference material analyses was slightly lower than is normally seen.

PACF concluded that these anomalies should have no affect on the interpretation of the data.

Data Interpretation

The results for Hg in skin-off and skin-on fillets were compared to the MDCH and the USFDA criteria for exceedences that would suggest the need for consumption advisories. The results were also compared to the 1988 data set to assess any change in concentration over time. For each species, linear correlation analysis was performed to establish a relationship between Hg concentration in fillets and fish size (total body length and whole fish weight). When established, the relationships were used to predict the sizes at which criteria were exceeded. Linear correlation analysis was performed to establish a relationship between log transformed total body length and whole fish weight. Linear correlation analysis was also performed on Hg concentrations in fillets; skin-off versus skin-on. This relationship was then compared to the linear 1:1 relationship of concentrations to evaluate whether the skin-on fillets do constitute the worst case Hg exposure.

Results

A total of 125 fish from four species were analyzed; 48 northern pike, 50 yellow perch, 17 white sucker and 10 pumpkinseed. The results of the Hg analysis for the 250 fillets are summarized in Table 1. All four species showed some detectable levels of Hg. Individual values ranged from less than reportable detection levels to 1.69 *u*g/g Hg, wet wt. in a yellow perch skin-on fillet. In general, the levels were higher in fillets from northern pike and yellow perch than in white sucker and pumpkinseed, consistent with the trophic level status of the species.

Exceedence of Criteria

Twenty two fillet samples derived from 13 individual fish exceeded either the MDCH or USFDA criteria for Hg, all from northern pike and yellow perch. These 13 fish were collected from 6 different sampling locations, with 6 of the fish taken from Marsh Creek Pool. Two fish with fillet samples exceeding criteria were taken from Pools A1 and H, and one fish each from Pools M2, I, and C3. Nine of the 13 fish had both fillets, skin-off and skin-on, exceed one or more criteria. All fillets from white sucker and pumpkinseed were well below the criteria.

For northern pike, seven individual fish from four different collection locations (Pools A1, I, M2 and Marsh Creek) exceeded the criteria. Five skin-off fillets and seven skin-on fillets exceeded the MDCH's limited consumption criteria (0.5-1.5 *u*g/g Hg, wet wt.) advising one meal per month/week (depending on the target population). No fillets exceeded the MDCH's no consumption category (>1.5 *u*g/g Hg, wet wt.). Two skin-off fillets and one skin-on fillet exceeded the USFDA's tolerance level for Hg in fish for interstate commerce (>1.0 *u*g/g Hg, wet wt.). The smallest pike to exceed the criteria measured 1077.9 g (2.4 lb) whole fish

weight and 570 mm (22.4 in) total body length. The largest was 3593.3 g (7.9 lb) whole fish weight and 850 mm (33.5 in) total body length.

For yellow perch, six individual fish from four different locations (Pools A1, C3, H and Marsh Creek) exceeded the criteria. Five skin-off fillets and five skin-on fillets exceeded the MDCH's limited consumption criteria, while one skin-on fillet exceeded the no consumption criteria. Two skin-on fillets exceeded the USFDA's tolerance level for Hg. The smallest yellow perch to exceed the criteria measured 50.4 g (0.1 lb) whole fish weight and 160 mm (6.3 in) total body length. The largest was 165.7 g (0.4 lb) whole fish weight and 230 mm (9.1 in) total body length.

Comparison to 1988 Data

Although the 1988 data set (Best *et al.* 1995) is limited by QA/QC concerns, small sample size, and skin-off fillet data only, some comparisons in the Hg levels may be made to the present data set. In 1988, seven of 14 skin-off fillets from northern pike exceeded the MDCH and USFDA criteria, with exceeding values in the range of 0.51-1.4 *ug*/g Hg, wet wt. (Table 2). Those 7 fish ranged in size from 419-2571.2 g (0.9-5.7 lb) whole fish weight and 425-710 mm (16.7-28.0 in) total body length. These seven fish were taken from two of the four pools sampled; Pools A1 and M2. In general, this matches well in size, concentration and location with the present data set for those fish which exceed the criteria. This suggests that Hg in northern pike fillets has remained stable from 1988 to the present time.

In 1988, none of the yellow perch skin-off fillets exceeded the MDCH or USFDA criteria for Hg (Table 2). However, only four fish were collected and all four were from a single pool, Pool C3. The 1988 fish generally were of a larger size than the yellow perch which exceeded the criteria from the present study. One perch that exceeded the criteria in the present study was from Pool C3. From this limited comparison, one might conclude that Hg levels in yellow perch fillets have risen from 1988 to the present time.

In 1988, only two white sucker skin-off fillets were analyzed, both from Pool A1 (Table 2). While neither exceeded the MDCH or USFDA criteria for Hg, they are nearly an order of magnitude higher than the levels detected in the present study. This may suggest that Hg levels in white sucker fillets have fallen from 1988 to the present time, and/or there are differences in Hg exposure/uptake among pools.

Relationship between Length and Weight of Fish

All four species exhibited a good linear relationship between log transformed whole fish weight and total body length (Figure 1a-1d). If one assumes that the general size of a fish is an indicator of age, then either measure of size may be a general indicator of age. Actual age was not determined from the scale samples. If there is a demonstrated relationship between size of fish and the level of Hg in fillets, then either measure of size may be used in establishing size-related consumption advisories. However, weight is expected to vary more than length due to variation in seasonal metabolism and incidences of feeding.

Relationship between Hg in Fillets and Size of Fish

a. Northern Pike

The northern pike samples exhibit significant positive correlations between measures of Hg in fillets, skin-off and skin-on, and measures of fish size, total body length and whole fish weight (Figures 3a, 4a, 5a, 6a). Using the linear relationships for total body length, the calculated lines exceed the MDCH criteria for limited consumption at a fish length of 677.9 mm (26.7 in) for skin-off fillets (Figure 3a), and at a fish length of 683.5 mm (26.9 in) for skin-on fillets (Figure 4a). All five skin-off fillets that exceeded the MDCH criteria also exceeded the calculated exceedence length of 677.9 mm (Figure 3a). Whereas, only five of the seven skin-on fillets that exceeded the MDCH criteria also exceeded the calculated exceedence length of 683.5 mm (Figure 4a). This suggests that skin-off fillets may be more predictive of MDCH Hg criteria exceedence. The calculated lines did not exceed the USFDA Tolerance Level for either fillet type within the range of total body lengths.

Similar relationships occur between Hg in fillets and whole fish weight. Using the linear relationships for whole fish weight, the calculated lines exceed the MDCH criteria for limited consumption at a fish weight of 1796.0 g (3.96 lb) for skin-off fillets (Figure 5a), and at a fish weight of 1835.0 g (4.05 lb) for skin-on fillets (Figure 6a). As was the case for length, all five skin-off fillets that exceeded the MDCH criteria also exceeded the calculated exceedence weight of 1796.0 g (Figure 5a). Whereas, only five of the seven skin-on fillets that exceeded the MDCH criteria also exceeded the calculated exceedence weight of 1835.0 (Figure 6a). This also supports the above suggestion that skin-off fillets may be more predictive of MDCH Hg criteria exceedence. The calculated lines did not exceed the USFDA Tolerance Level for either fillet type within the range of whole fish weights.

b. Yellow Perch

For yellow perch, no relationships could be demonstrated between Hg in either fillet type and either measure of fish size (Figure 3b, 4b, 5b, 6b). While exceedences of Hg criteria did occur, no predictable relationship with size was evident. Contrary to expectation, those fillets that exceeded MDCH or USFDA criteria were derived from medium to small-sized fish within the range of sampled sizes. For skin-off fillets, five samples exceeded only the MDCH criteria for limited consumption (Figure 3b, 5b). Of the five skin-on fillets to exceed the MDCH criteria for limited consumption, two also exceeded the USFDA's Tolerance Level, and one exceeded the MDCH criteria for no consumption (Figure 4b, b).

c. White Sucker and Pumpkinseed

While both the white sucker and pumpkinseed exhibit good to significant positive correlations between Hg in either fillet type and either measure of fish size (Figure 3c-3d, 4c-4d, 5c-5d, 6c-6d), the levels of Hg in fillets from both species fell well below any criteria and pose little risk to human consumption. The relationships are stronger for the white sucker, owing in part to a larger sample size.

Relationship between Hg in Fillets, Skin-Off versus Skin-On

This relationship is investigated to see if skin-off fillets represent the worst case scenario for Hg exposure to humans. Presumably, with the deposition of Hg predominantly in muscle tissue, the removal of the skin and subcutaneous fat should result in higher concentrations of Hg in skin-off fillet samples when compared to its paired skin-on fillet. The results show that the correlation between Hg in paired skin-off and skin-on fillets closely approximates an equal 1:1 ratio for all four species (Figure 2a-2d). Although not measurably different from the 1:1 relationships, the correlations do show a trend toward higher concentrations in the skin-off fillets. Ninety of the 125 paired fillet samples exhibited higher levels of Hg in skin-off fillets than in skin-on fillets. The trend was also evident for paired fillets for each species; 34 of 48 northern pike, 36 of 50 yellow perch, 14 of 17 white sucker, and 6 of 10 pumpkinseed.

Discussion

Our data supports the MDCH's special consumption advisory for Hg in fish from inland lakes. Clearly northern pike and yellow perch exceed the MDCH criteria in a consistent manner. That these two species should exceed the criteria, whereas white sucker and pumpkinseed did not, is likely indicative of their more piscivorous food habits and more elevated trophic positions. To have exceedences for fish from half of the sampling locations suggests that any specific consumption advice contemplated by the Seney NWR or mandated by the MDCH would be appropriate for waters within the entire refuge.

For the northern pike, the significant positive correlation between Hg in fillets and fish size, would allow for the possible issuing of size-specific advice for limited consumption. Based on the exceedence of the MDCH limited consumption criteria (0.5-1.5 *ug*/g Hg, wet wt.) at a calculated total body length of 675-680 mm (~26.5 in), this would allow for northern pike under this size to be excluded from any consumption advice. Fish over this size would be subject to limited consumption; one meal per week advised for the general population, and one meal per month advised for pregnant women, nursing mothers, women who plan to have children, and children under 15 years of age.

An alternative to using the calculated fish size would be to use the smallest actual northern pike to exceed the MDCH criteria for limited consumption. Using this method, northern pike greater than 570 mm total body length (22.4 in) would trigger the limited consumption advisory. This would be more restrictive and protective of human health. The results of either method would be similar to the limited consumption advisory issued by the MDCH for northern pike >558.8 mm in length (22 in) in the Manistique River outside the refuge.

For yellow perch, the situation is clouded by the lack of a relationship between Hg concentration in fillets and fish size, and the exceedence of the MDCH's no consumption criteria. While Seney NWR has in the past planted yellow perch in one or more pools on the refuge, all sources of fish have come from other refuge pools. Therefore, the fish with high Hg concentrations can not be attributed to off refuge sources. No explanation is offered for

the elevated Hg levels in the small to medium-sized perch. Based on these inconsistencies and the exceedence of the no consumption criteria, it may be necessary to implement a no consumption policy for yellow perch taken from Seney NWR. A catch and release fishery could still occur.

For those species of fish covered under the MDCH special advisory for Hg, but that were not collected or analyzed, it may be necessary to maintain the special advisory for those species that are known to occur on the refuge. This seems prudent in the absence of any data specific to these species.

There is insufficient data from the initial fish collections in 1988 to establish a trend over time for Hg in edible fillets. However, the elevated levels of Hg found in both collections, suggest that this issue will need to be revisited in the future with additional collections and analyses.

Recommendations

Based on the above findings, the following recommendations are offered for consideration by the Seney NWR:

1) At the request of Seney NWR, ELFO will submit the complete data set to MDCH, Environmental Epidemiology Division for formal review and possible issuance of consumption advisories specific to Seney NWR. The earliest formal advice provided would likely be available to the public in the year 2000, as provided in the Michigan Fishing Guide for the period of April 1, 2000 to March 31, 2001.

2) Beginning in 2000 and continuing until the possible issuance of a formal advisory from MDCH, Seney NWR will issue the following interim consumption advice for all refuge waters:
    a) no consumption of yellow perch,
    b) limited consumption of northern pike greater than 570 mm total body length (22.4 in), and
    c) limited consumption of rock bass, or crappie over 228.6 mm (9 in) in length, or bass, walleye, or muskellunge of any size, if these species are known to occur in refuge waters. (At this time, black crappie, walleye and smallmouth bass are known to occur.)

    Limited consumption is defined as one meal per week for the general population, and one meal per month for pregnant women, nursing mothers, women who plan to have children, and children under 15 years of age.

3) Seney NWR will initiate an outreach program to educate and alert visitors and sport fishermen to the refuge of the existing special advisory for Hg in fish statewide, the interim

advisory for Hg in fish specific to Seney NWR, and any formal advisory for Hg in fish to be issued in the future by the MDCH specific to Seney NWR.

4) Seney NWR, ELFO and Green Bay FRO will develop a monitorring protocol to quantify levels of Hg in edible fish fillets derived from refuge pools in future years.

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Table 1. Mercury (ug/g, wet weight) in Fish Fillets, Skin-Off and Skin-On, 1996-97.

Sample	Date Collected	Pool	Total Body Length (mm)	Weight Whole Fish (g)	Hg (ug/g, wet weight) Fillet Skin-Off	Fillet Skin-On
Northern Pike:						
96-01	7/18/96	G	460	439.4	0.231	0.203
96-02	7/18/96	G	480	599.2	0.185	0.125
96-03	7/18/96	G	375	225.4	0.0388	0.07
96-04	7/17/96	J	415	336.5	0.114	0.0811
96-05	7/17/96	J	415	383.7	0.116	0.133
96-06	7/17/96	J	390	293.7	0.0472	0.0522
97-01	7/22/97	C3	405	357.8	0.136	0.105
97-02	7/22/97	C3	360	241.7	0.08	0.0721
97-03	7/22/97	C3	420	387.9	0.069	0.107
97-04	8/18/97	A1	585	939.6	0.298	0.267
97-05	6/05/97	M2	605	1294.5	0.282	0.264
97-06	6/13/97	G	655	1520.3	0.113	0.186
97-07	6/05/97	MC	655	1579.7	0.408	**0.556**
97-08	6/04/97	MC	580	1315.8	0.162	0.102
97-09	6/05/97	M2	645	1595.4	0.293	0.248
97-10	6/04/97	MC	445	469.2	0.22	0.179
97-11	6/04/97	MC	605	1249	0.267	0.191
97-12	6/04/97	MC	810	3142.2	**1.03**	**1.29**
97-13	6/04/97	MC	850	3593.3	**1.02**	**0.784**
97-14	6/04/97	C2	625	1363	0.208	0.184
97-15	6/05/97	M2	630	1333.6	0.224	0.327
97-16	6/04/97	C2	540	1006.2	0.222	0.179
97-17	6/05/97	MC	525	762.4	0.239	0.248
97-18	6/05/97	MC	575	1107.9	0.283	0.295
97-19	6/04/97	MC	495	690.6	0.358	0.268
97-20	6/04/97	C2	495	644.9	0.267	0.233
97-21	6/11/97	I	545	700.6	0.321	0.348
97-22	6/06/97	RD	485	618.4	0.252	0.235
97-23	6/10/97	D	650	1416.8	0.32	0.282
97-24	6/08/97	M2	610	1257.2	0.385	0.311
97-25	6/10/97	D	565	1077.7	0.302	0.298
97-26	6/08/97	A2	615	1187.6	0.183	0.157
97-27	6/05/97	M2	725	2230.6	**0.573**	**0.528**
97-28	6/08/97	A2	595	1119	0.192	0.165
97-29	6/08/97	A2	545	670.1	0.273	0.21
97-30	6/06/97	RD	555	855	0.481	0.439
97-31	6/08/97	C2	590	1158.1	0.319	0.269

Table 1. continued

Sample	Date Collected	Pool	Total Body Length (mm)	Weight Whole Fish (g)	Hg (ug/g, wet weight) Fillet Skin-Off	Fillet Skin-On
Northern Pike						
97-32	6/06/97	RD	555	899	0.393	0.352
97-33	6/10/97	D	580	1104.4	0.24	0.217
97-34	6/10/97	D	570	749.9	0.471	0.407
97-35	6/06/97	RD	570	972.1	0.188	0.162
97-36	6/05/97	MC	770	2599.3	**0.912**	**0.863**
97-37	6/08/97	A1	550	924.7	0.288	0.257
97-38	6/11/97	I	655	1660.3	0.462	0.355
97-39	6/05/97	MC	650	1777.5	0.491	0.373
97-40	6/06/97	I	570	1077.9	0.243	**0.793**
97-41	6/06/97	RD	620	1294.3	0.427	0.441
97-42	6/08/97	A1	705	1975.7	**0.726**	**0.743**
Yellow Perch						
96-01	7/17/96	J	205	92.7	0.04	0.0364
96-02	7/17/96	J	210	102.4	0.0364	0.0254
96-03	7/17/96	J	240	158.9	0.0495	0.0476
96-04	7/17/96	J	170	54.1	0.0256	0.0291
96-05	7/17/96	J	205	86.7	0.0367	0.0431
96-06	7/18/96	G	235	162.2	0.0339	0.0331
96-07	7/18/96	G	240	152.4	0.0268	0.0381
96-08	7/18/96	G	215	130.1	0.0381	0.0275
96-09	7/18/96	G	215	105	0.0424	0.02
96-10	7/18/96	G	240	166.7	0.0283	0.0288
96-11	7/18/96	G	275	243.2	0.055	0.0354
97-01	8/18/97	A1	280	237.3	0.192	0.164
97-02	8/18/97	A1	235	130.6	0.09	0.1
97-03	8/19/97	A2	255	199	0.119	0.0667
97-04	8/19/97	A2	245	162.2	0.0811	0.0673
97-05	7/23/97	D	250	191.2	0.0792	0.0769
97-06	7/23/97	D	250	193.1	0.0973	0.0789
97-07	8/18/97	H	240	190	0.0545	0.0396
97-08	8/18/97	H	225	165.7	0.05	**1.06**
97-09	8/18/97	H	230	159.4	**0.56**	**0.54**
97-10	7/24/97	MC	210	113	**0.696**	**0.565**
97-11	7/22/97	C3	210	122.8	**0.755**	**1.69**
97-12	8/18/97	A1	210	114.3	**0.936**	**0.99**
97-13	7/24/97	MC	160	50.4	**0.964**	< 0.0196

Table continued

Sample	Date Collected	Pool	Total Body Length (mm)	Weight Whole Fish (g)	Hg (ug/g, weight) Fillet Skin-Off	Fillet Skin-On
Yellow Perch						
97-14	7/24/97	MC	195	100	0.0187	0385
97-15	7/24/97	MC	235	168.2	0.0185	0.0172
97-16	7/22/97	C	185		0.0192	0.0196
97-17	7/23/97	D	185		0.0192	0.0185
97-18	7/24/97	MC	140	33.4	0.019	0.0187
97-19	7/24/97	MC	155		0.0182	0.02
	7/23/97		280	267.4	103	0.0991
97-21	7/23/97		275	234.1	.0762	0.0495
	7/23/97		260	200	0.06	0.0265
	7/23/97		240	163.1	0.0288	0.0196
	7/23/97		215	104.3	0472	0.028
	7/23/97		225		028	0.02
97-26	7/23/97		200	83.9	019	0.0172
97-27	7/23/97		185	80.4	0177	0.0194
	7/23/97		190	79.3	0189	0.0187
97-	7/23/97		175	62.9	0.0187	0.0198
97-30	7/23/97		225	138.3	0.04	0.02
97-31	7/23/97		245	158.5	0.037	0.0283
97-32	7/23/97		230	155.8	0.0435	0.0263
97-33	7/23/97		200	95.7	0.0283	0.02
97-34	7/23/97		195	78.3	0.0291	0.0194
97-35	7/23/97		185	71.1	0.0196	0.02
97-36	7/23/97		185	64.7	0.0185	0.0192
97-37	7/23/97		210	115.2	0.02	0.0198
97-38	7/23/97		210	86.4	0.02	0.019
97-39	7/23/97		200	92.3	0.0196	0.01
White Sucker						
97-01	8/18/97	H	430	1128	0648	0.0545
97-02	8/18/97	H	470	1323.3	0.0541	0.0513
97-03	8/18/97	H	415	902	0.036	0.0342
97-04	8/18/97	H	400	766.8	0.025	0.03
97-05	8/18/97	H	410	844.9	0.0377	0.0189
97-06	8/18/97	H	415	884.4	0.0348	0.0254
97-07	7/23/97		455	1016.8	0.0847	0.0792
	7/23/97		490	1147.5	0.117	0.09
	8/18/97	H	425	952.5	0.0392	0.0183

Table 1 continued.

Sample	Date Collected	Pool	Total Body Length (mm)	Weight Whole Fish (g)	Hg (ug/g, wet weight) Fillet Skin-Off	Fillet Skin-On
White Sucker:						
97-10	8/18/97	H	470	1206.3	0.0973	0.0847
97-11	8/18/97	H	395	766.4	0.028	0.0351
97-12	8/18/97	H	405	830	0.0294	0.0261
97-13	8/18/97	H	340	457.9	0.0261	0.03
97-14	7/23/97	D	255	187.9	0.0196	0.0185
97-15	8/19/97	A2	215	96.8	0.0294	< 0.0187
97-16	7/24/97	MC	200	105	0.0183	0.0171
97-17	7/22/97	C3	355	524.1	0.0648	0.041
Pumpkinseed:						
97-01	7/24/97	MC	130	50.7	0.042	0.104
97-02	7/24/97	MC	140	69.7	0.068	0.0577
97-03	7/24/97	MC	130	57.7	0.0381	0.0278
97-04	7/24/97	MC	125	43.1	0.0495	0.0504
97-05	7/24/97	MC	125	49.4	0.0556	0.0396
97-06	7/24/97	MC	125	41.5	0.0345	0.0396
97-07	7/24/97	MC	115	34.5	0.0294	0.0288
97-08	7/24/97	MC	125	45.4	0.0561	0.05
97-09	7/24/97	MC	140	65.1	0.0776	0.0841
97-10	7/24/97	MC	130	52.6	0.09	0.0667

MC - Marsh Creek Pool.
RD - Riverside Dike Pools along Driggs River.
Total body length rounded to nearest 5 mm.
Results reported to 3 significant digits.
Bolded result exceeds USFDA tolerance level for Hg in fish for interstate commerce (> 1.0 ug/g, wet wt.) and/or MDCH criteria for Hg in fish (0.5-1.5 ug/g, wet wt. for limited consumption; >1.5 ug/g, wet wt. for no consumption).
"<" - Result < reported detection limit.

Table 2. Mercury (ug/g, wet weight) in Fish Fillets, Skin-Off, 1988.

Sample	Date Collected	Pool	Total Body Length (mm)	Weight Whole Fish (g)	Hg (ug/g, wet wt.) Fillet Skin-Off
Northern Pike:					
88-30	4/26/88	M2	710	2571.2	* **1.4**
88-32	4/26/88	M2	620	1683.5	* **0.96**
88-26	4/28/88	M2	600	1272.3	* **1.1**
88-28	4/28/88	M2	435	473.3	**0.59**
88-40	5/02/88	A1	665	1636.7	* 0.44
88-38	4/29/88	A1	525	894.7	**0.53**
88-42	5/02/88	A1	445	520.8	* **0.51**
88-34	4/29/88	A1	460	489.3	0.4
88-36	4/29/88	A1	425	419	**0.55**
88-46	4/20/88	C3	410	388.6	0.16
88-48	4/20/88	C3	380	272.2	0.17
88-44	4/20/88	C3	345	233.3	0.22
88-52	6/18/88	E	560	1227.6	0.43
88-50	6/16/88	E	545	1154.6	0.18
Yellow Perch:					
88-54	4/20/88	C3	300	318.3	0.45
88-58	4/20/88	C3	250	243.7	0.28
88-60	4/20/88	C3	265	227.6	0.39
88-56	4/20/88	C3	255	199.5	0.42
White Sucker:					
88-67	4/29/88	A1	400	937.3	0.19
88-69	4/29/88	A1	375	836.3	0.21

Total body length rounded to nearest 5 mm.
Results reported to 2 significant digits.
Bolded result exceeds USFDA tolerance level for Hg in fish for interstate commerce (> 1.0 ug/g, wet wt.) and/or MDCH criteria for Hg in fish (0.5-1.5 ug/g, wet wt. for limited consumption; >1.5 ug/g, wet wt. for no consumption).
"*" - Result is actual result from PACF; all other results are estimates using correction factor (1.48) derived from mean of the ratio of results (PACF:contract laboratory).
Data from Best, D.A., T.J. Kubiak and D.E. Boellstorff. 1995. Survey of contaminants in soils and biota at the Seney National Wildlife Refuge. U.S. Fish Wildl. Serv., East Lansing Field Office. 21 pp.

Figure 1. Location of Referenced Pools and Streams on Seney NWR.

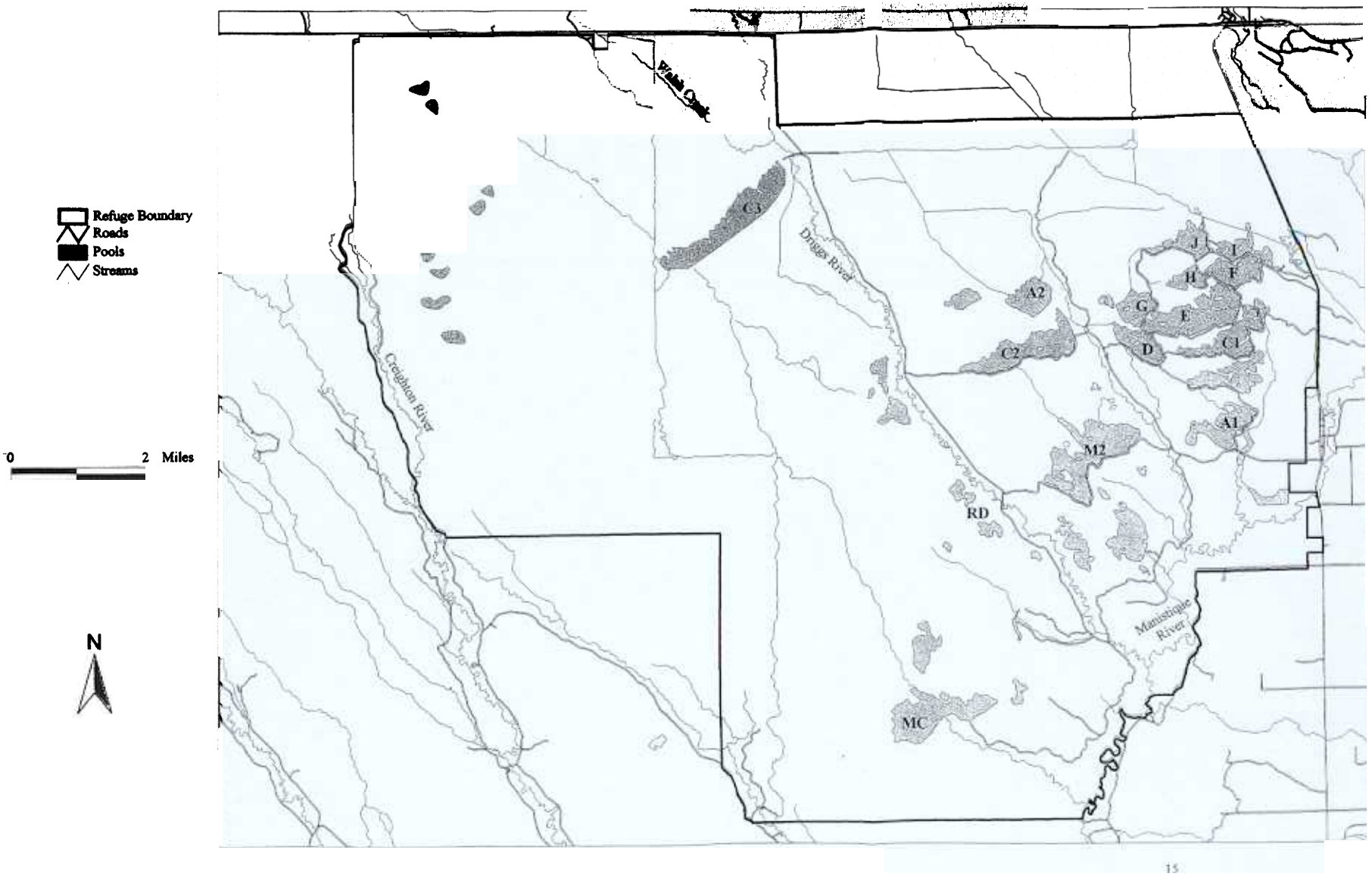
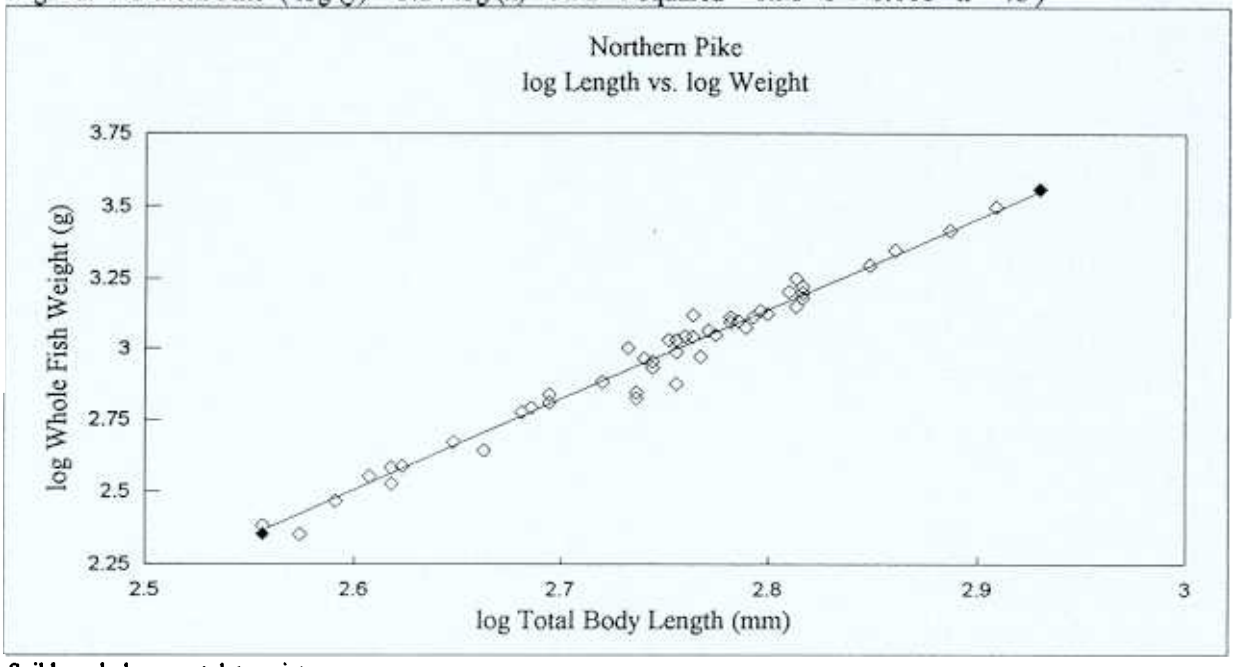


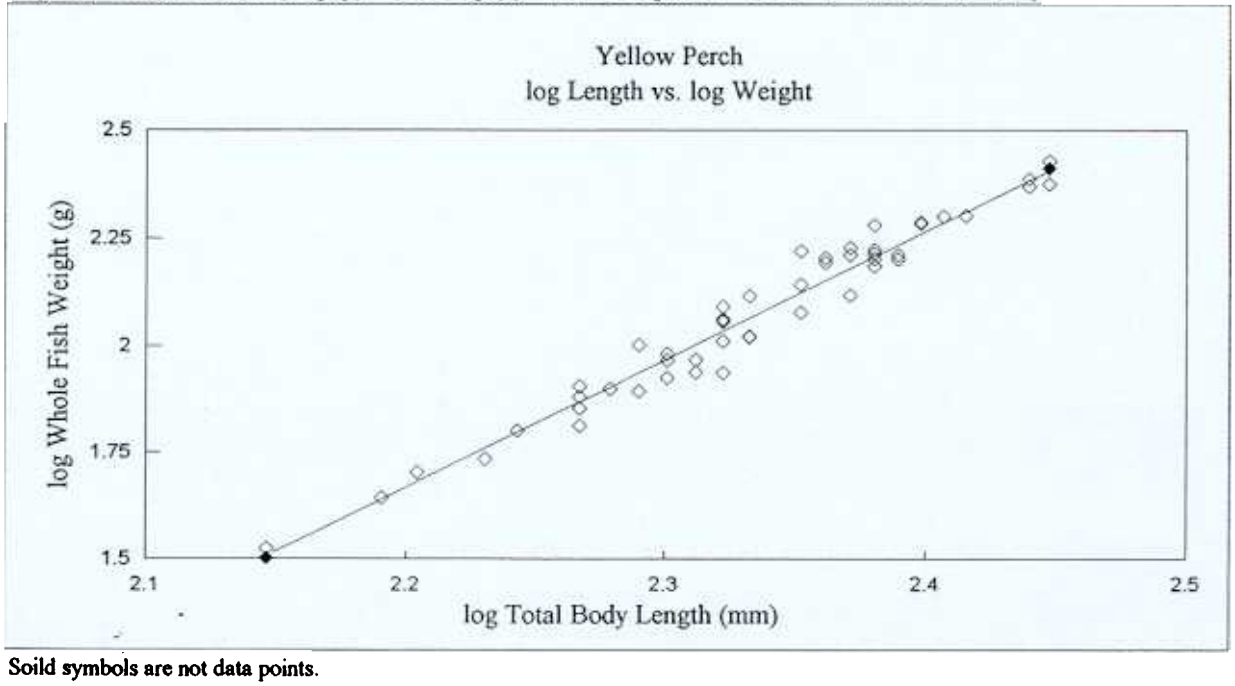
Figure 2. Relationship between log Total Body Length (mm) and log Whole Fish Weight (g).

Fig. 2a. Northern Pike (log (y) = 3.24 log (x) - 5.92 r-squared = 0.98 P < 0.001 n = 48)



Soild symbols are not data points.

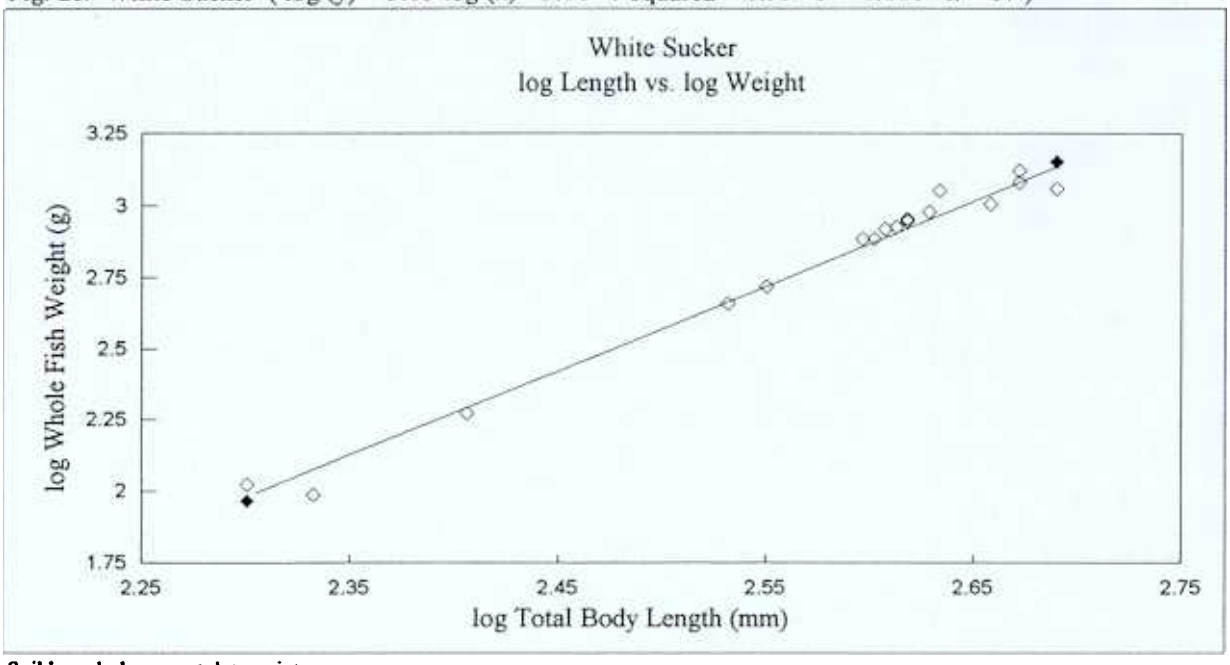
Fig. 2b. Yellow Perch (log (y) = 3.02 log (x) - 4.97 r-squared = 0.96 P < 0.001 n = 50)



Soild symbols are not data points.

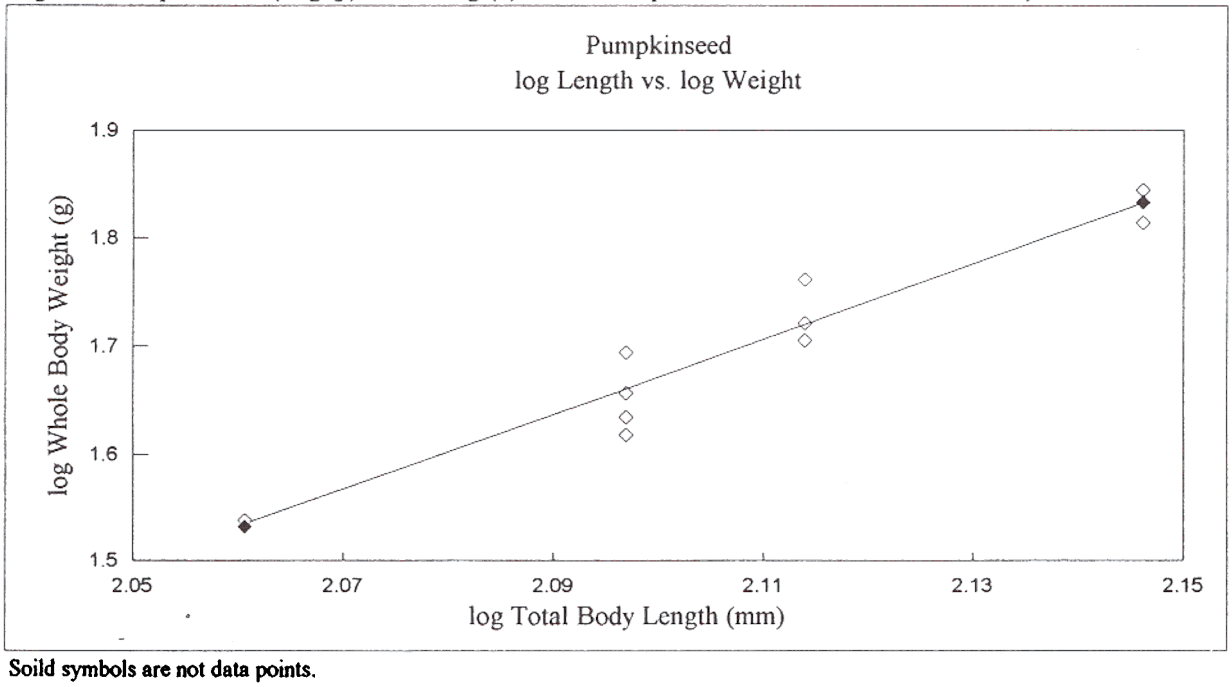
Figure 2. continued.

Fig. 2c. White Sucker (log (y) = 3.05 log (x) - 5.06 r-squared = 0.99 P < 0.001 n = 17)



Soild symbols are not data points.

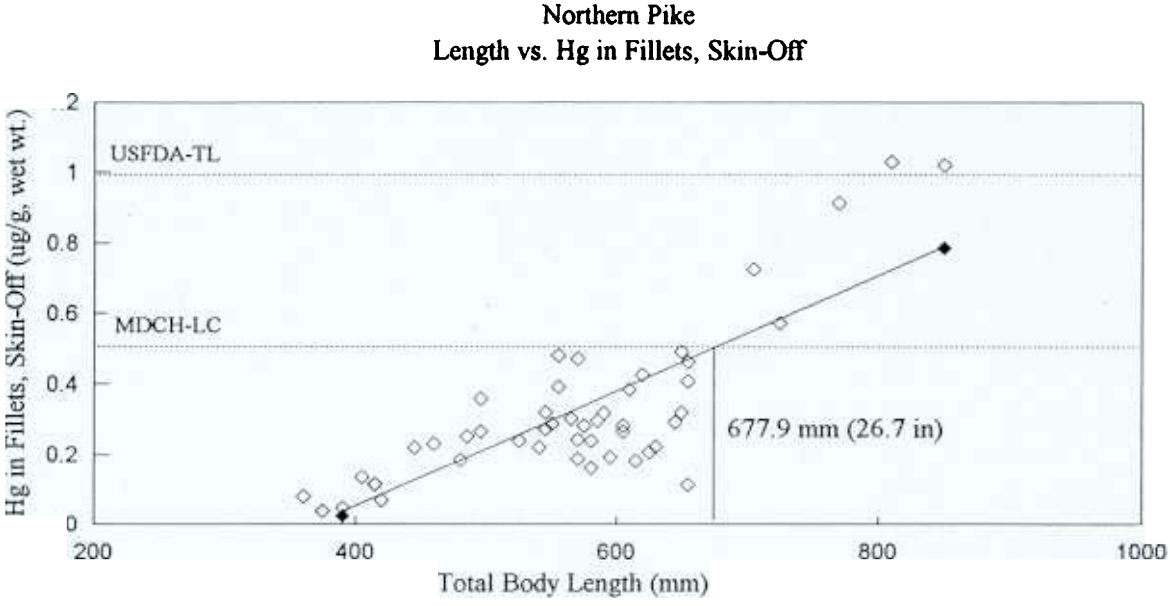
Fig. 2d. Pumpkinseed (log (y) = 3.53 log (x) - 5.74 r-squared = 0.92 P < 0.001 n = 10)



Soild symbols are not data points.

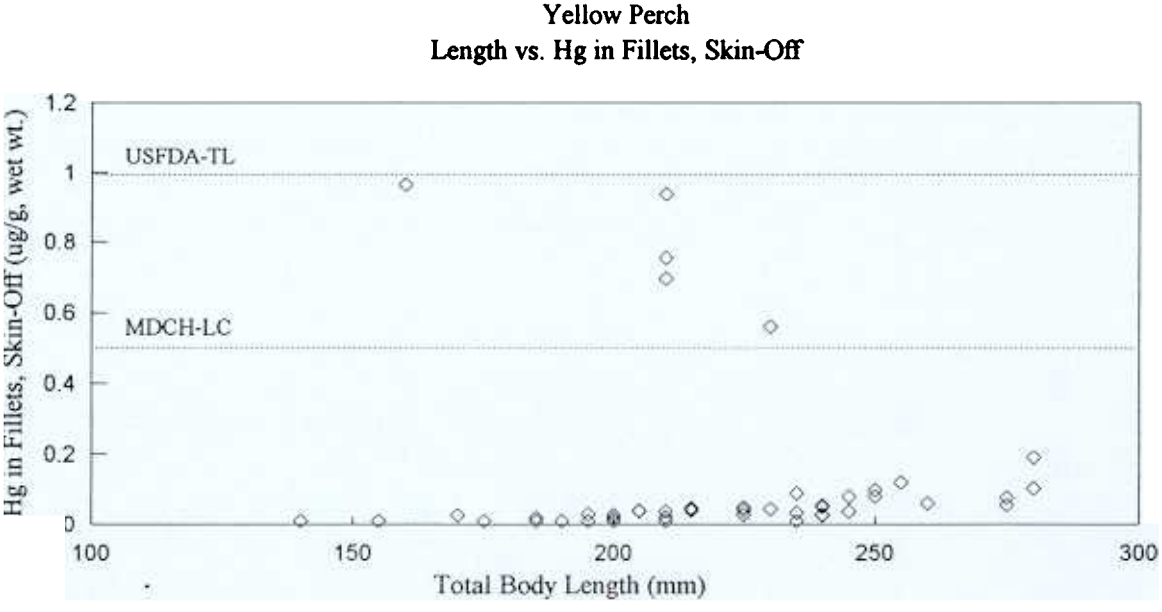
Figure 3. Relationship between Total Body Length (mm) and Hg in Fillets, Skin-Off (ug/g, wet wt.).

Fig. 3a. Northern Pike (y = 0.0017 x - 0.62 r-squared = 0.65 P < 0.001 n = 48)



Soild symbols are not data points.
TL - tolerance level, LC - limited consumption.

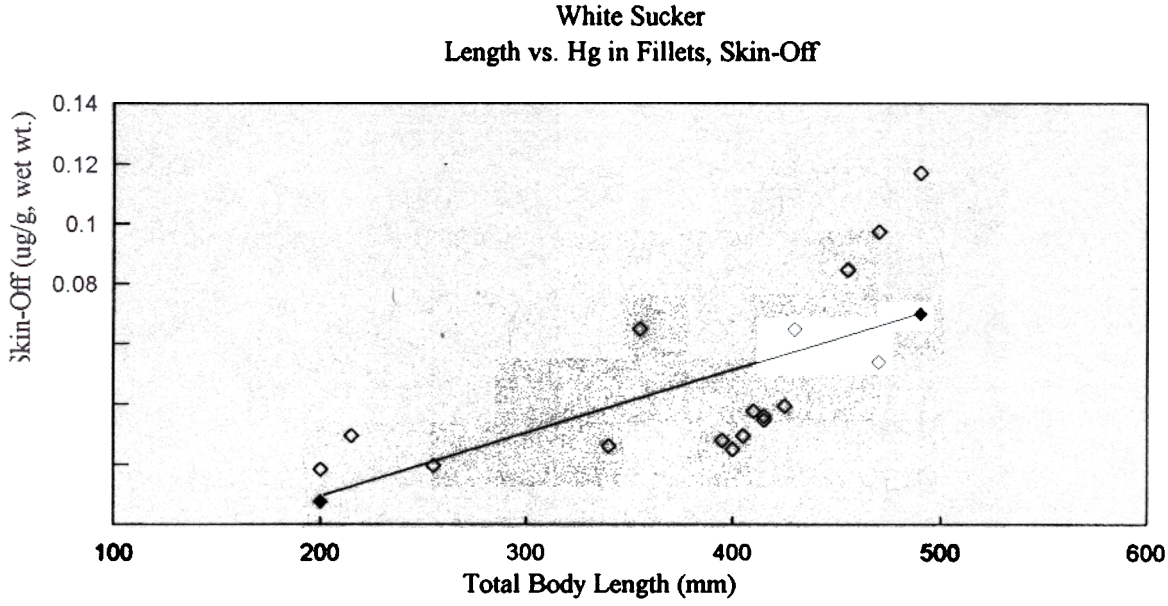
Fig. 3b. Yellow Perch



TL - tolerance level, LC - limited consumption.

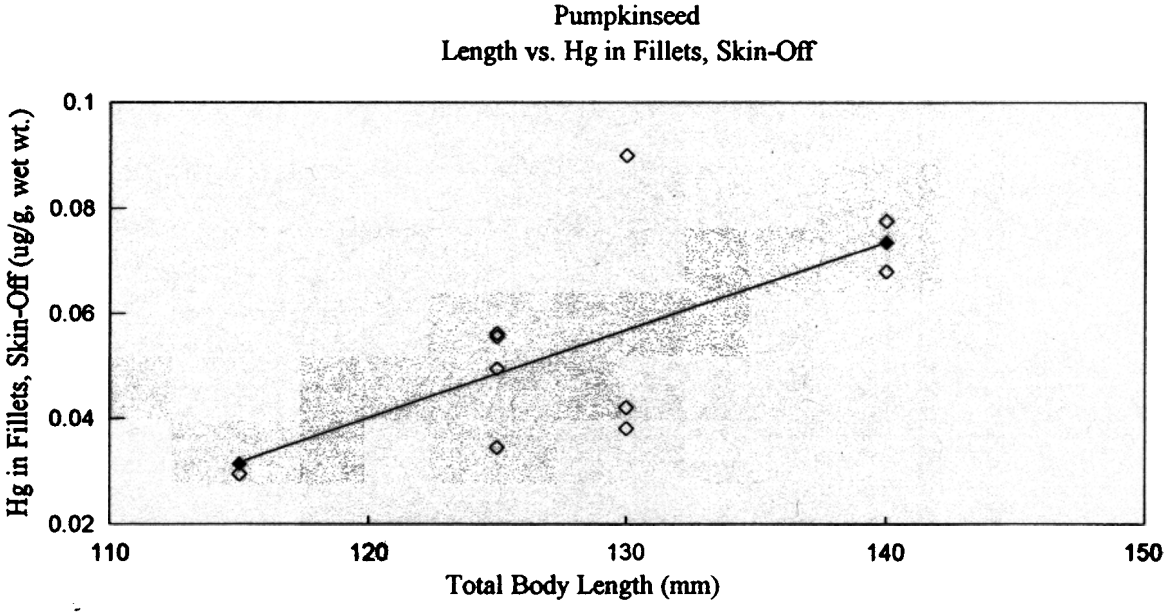
Figure 3. continued.

Fig. 3c. White Sucker (y = 0.00022 x - 0.035 r-squared = 0.41 P < 0.01 n = 17)



Soild symbols are not data points.

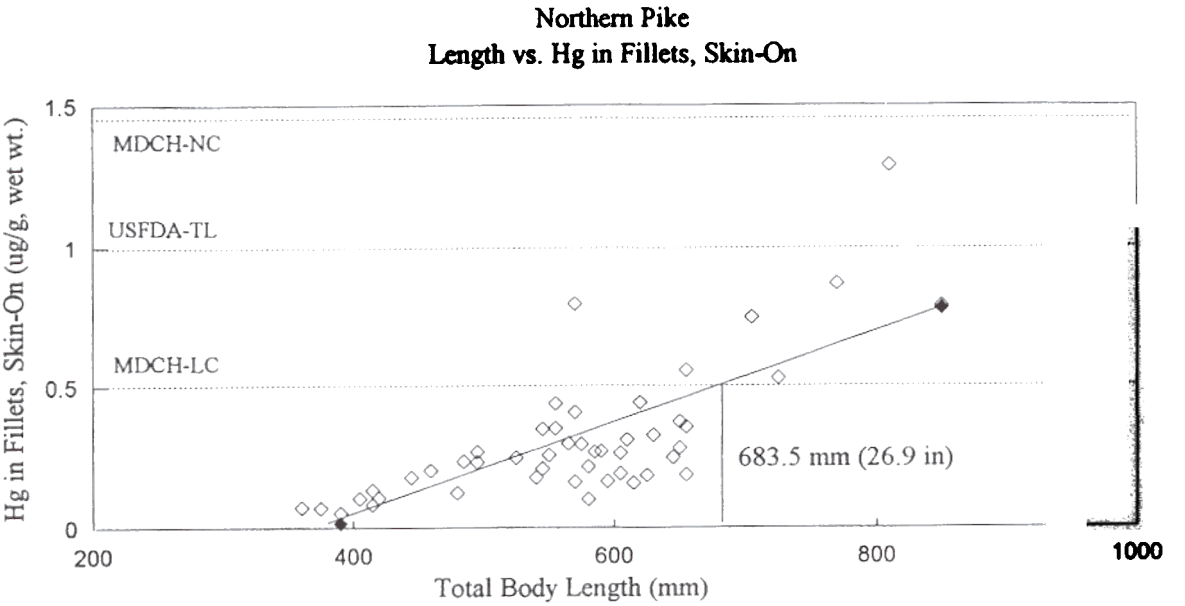
Fig. 3d. Pumpkinseed (y = 0.0017 x - 0.16 r-squared = 0.41 P < 0.05 n = 10)



Soild symbols are not data points.

Figure 4. Relationship between Total Body Length (mm) and Hg in Fillets, Skin-On (ug/g, wet wt.).

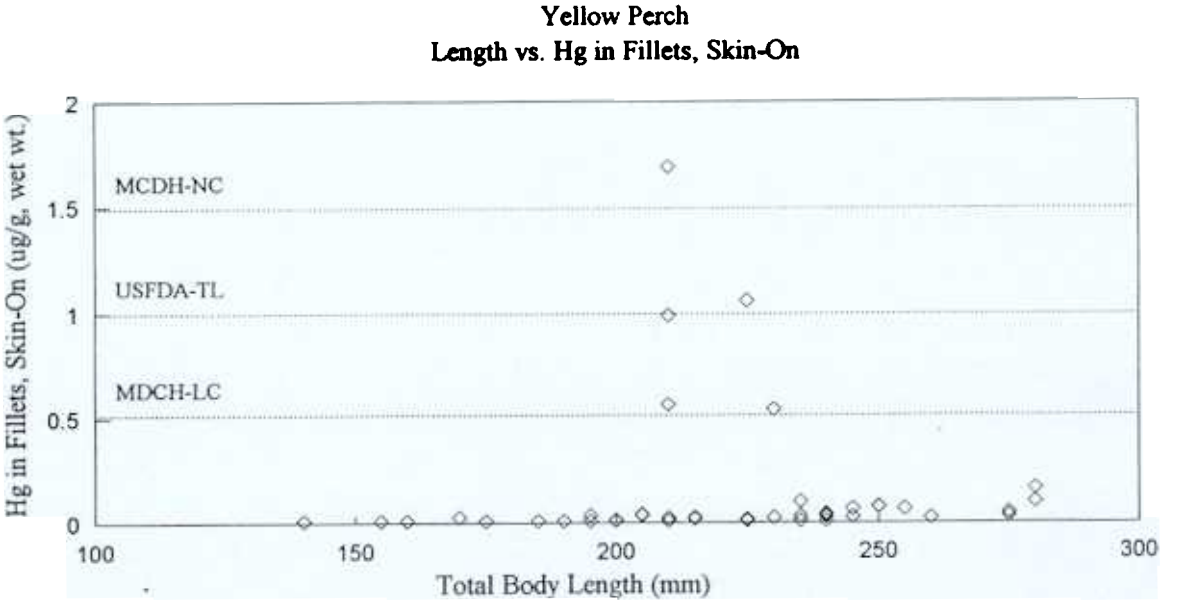
Fig. 4a. Northern Pike (y = 0.0016 x - 0.63 r-squared = 0.55 P < 0.001 n = 48)



Soild symbols are not data points.

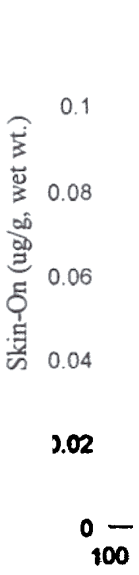
NC - no consumption, TL - tolerance level, LC - limited consumption.

Fig. 4b. Yellow Perch



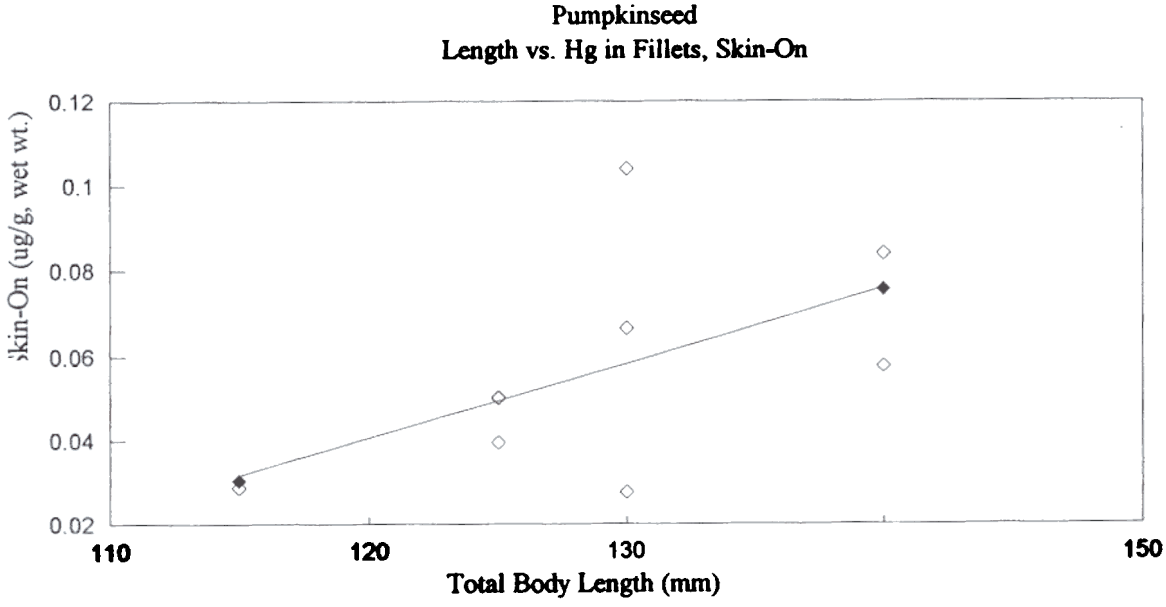
NC - no consumption, TL - tolerance level, LC - limited consumption.

Fig. 4c. White Sucker (y = 0.00020 x - 0.037 r-squared = 0.47 P < 0.01 n = 17)



Soild symbols are not data points.

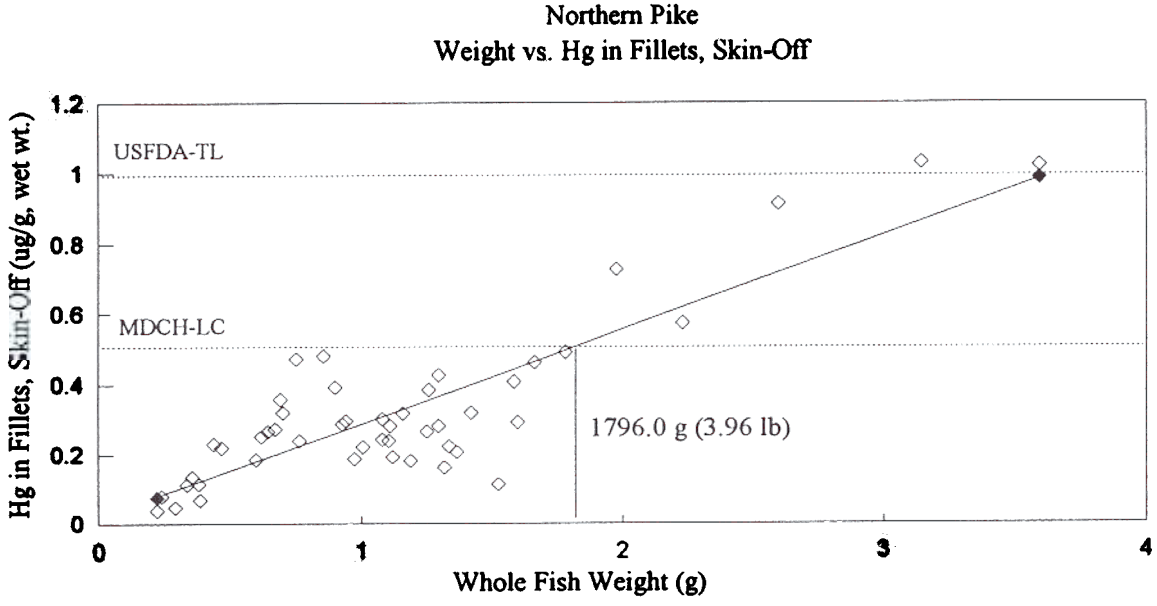
Fig. 4d. Pumpkinseed (y = 0.0018 x - 0.18 r-squared = 0.31 P < 0.10 n = 10)



Soild symbols are not data points.

Figure 5. Relationship between Whole Fish Weight (g) and Hg in Fillets, Skin-Off (ug/g, wet wt.).

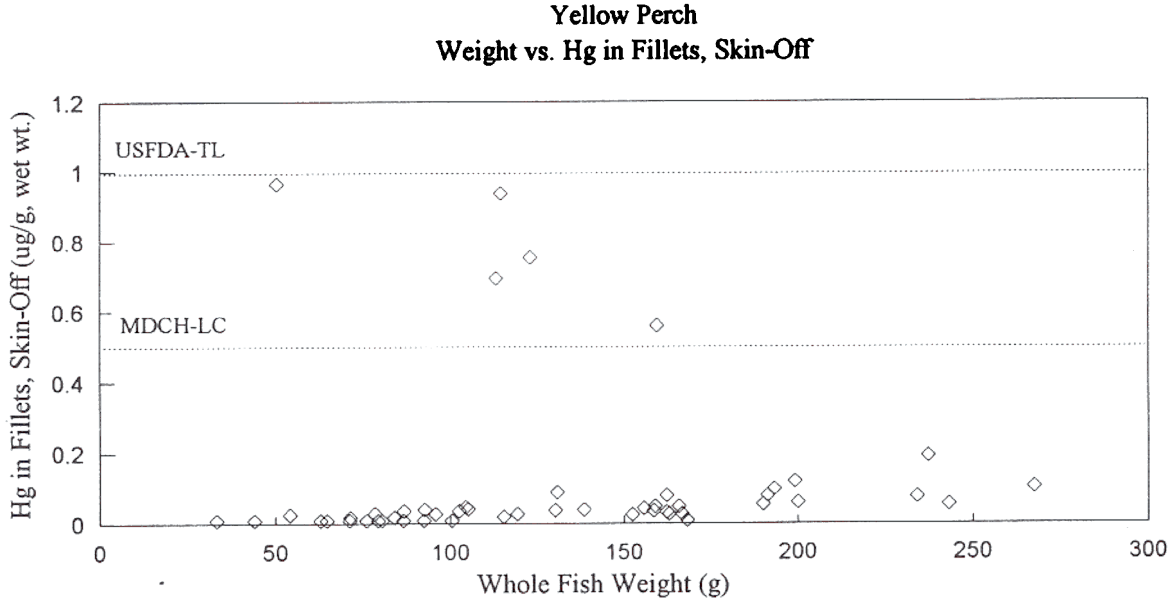
Fig. 5a. Northern Pike (y = 0.00027 x + 0.015 r-squared = 0.73 P < 0.001 n = 48)



Soild symbols are not data points.

TL - tolerance level, LC - limited consumption.

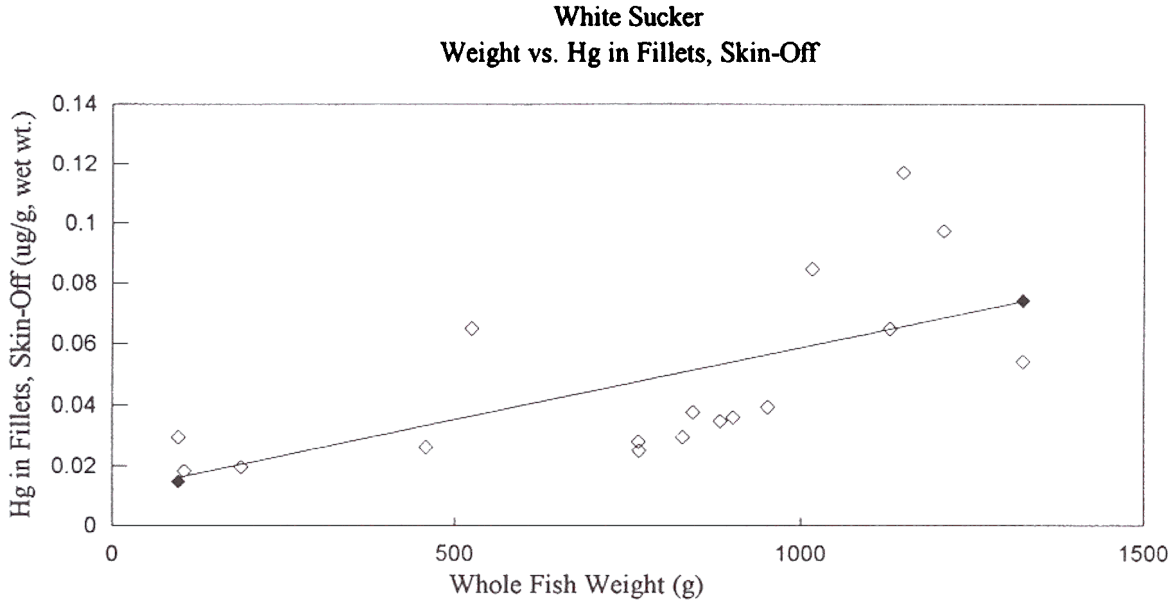
Fig. 5b. Yellow Perch



TL - tolerance level, LC - limited consumption.

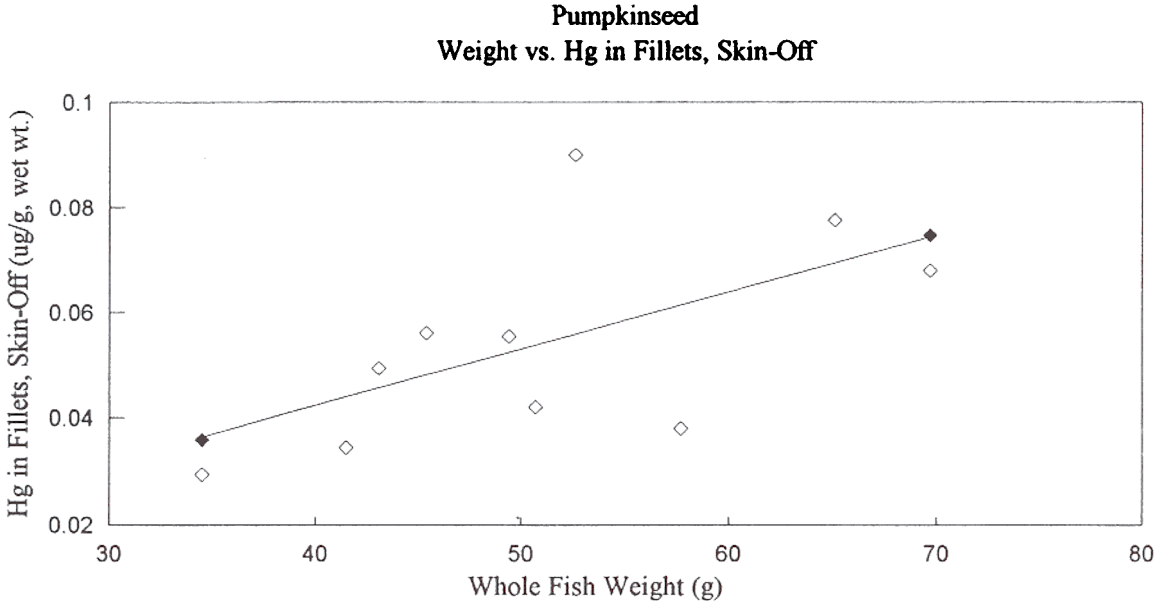
Figure 5. continued.

Fig. 5c. White Sucker (y = 0.000048 x + 0.010 r-squared = 0.40 P < 0.01 n = 17)



Soild symbols are not data points.

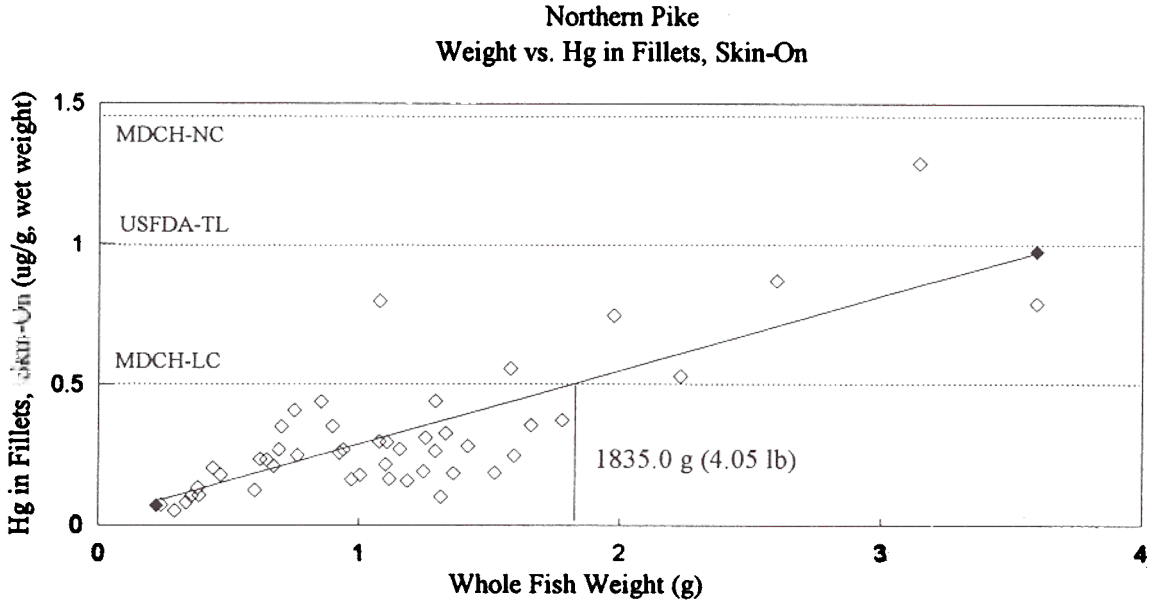
Fig. 5d. Pumpkinseed (y = 0.0011 x - 0.0020 r-squared = 0.37 P < 0.10 n = 10)



Soild symbols are not data points.

Figure 6. Relationship between Whole Fish Weight (g) and Hg in Fillets, Skin-On (ug/g, wet wt.).

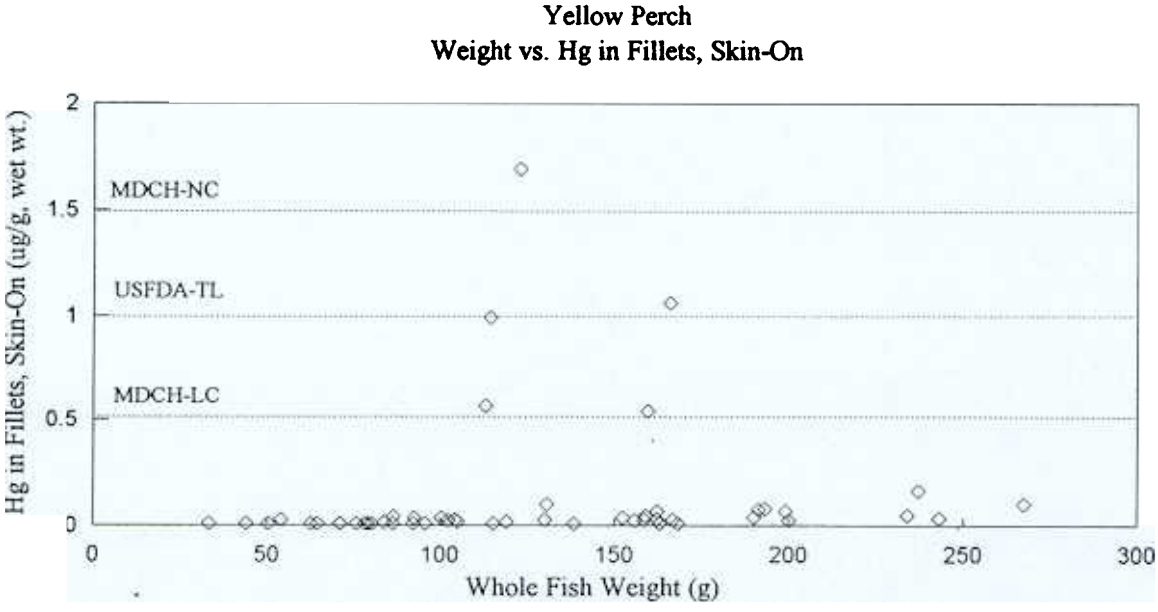
Fig. 6a. Northern Pike (y = 0.00027 x + 0.010 r-squared = 0.61 P < 0.001 n = 48)



Soild symbols are not data points.

NC - no consumption, TL - tolerance level, LC - limited consumption.

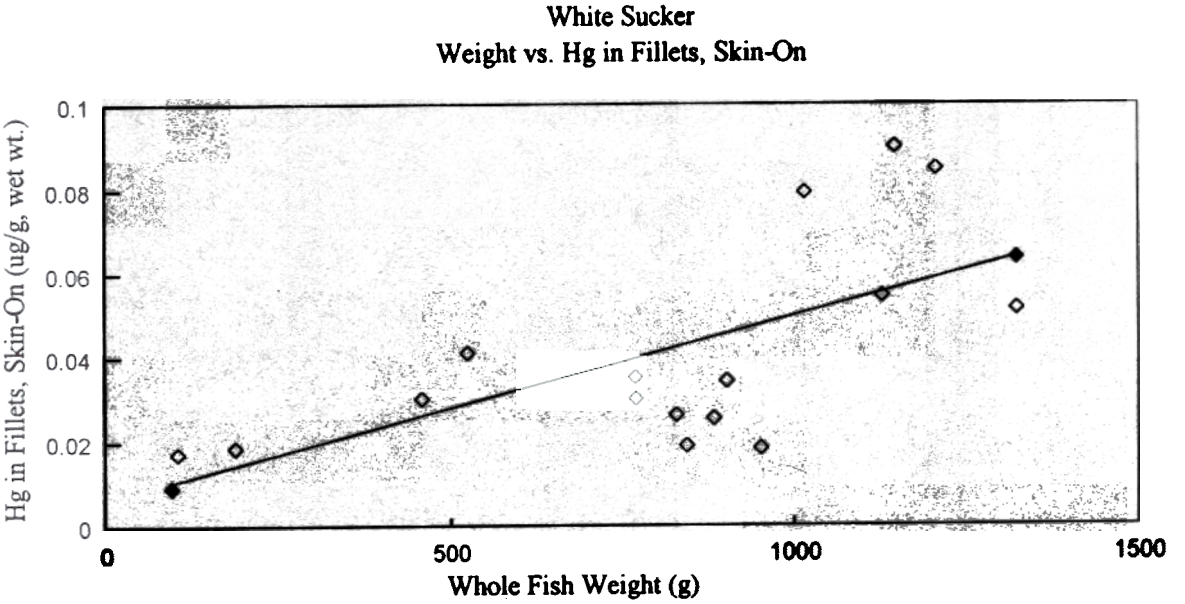
Fig. 6b. Yellow Perch



NC - no consumption, TL - tolerance level, LC - limited consumption.

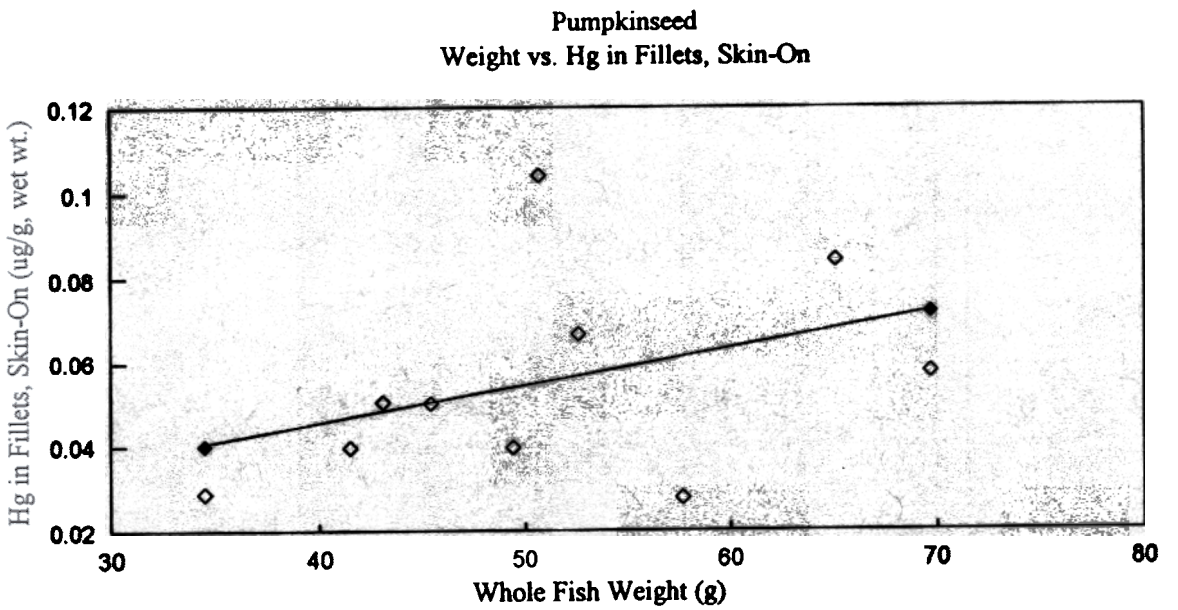
Figure 6. continued

Fig. 6c. White Sucker (y = 0.000045 x + 0.0046 r-squared = 0.46 P < 0.01 n = 17)



Soild symbols are not data points.

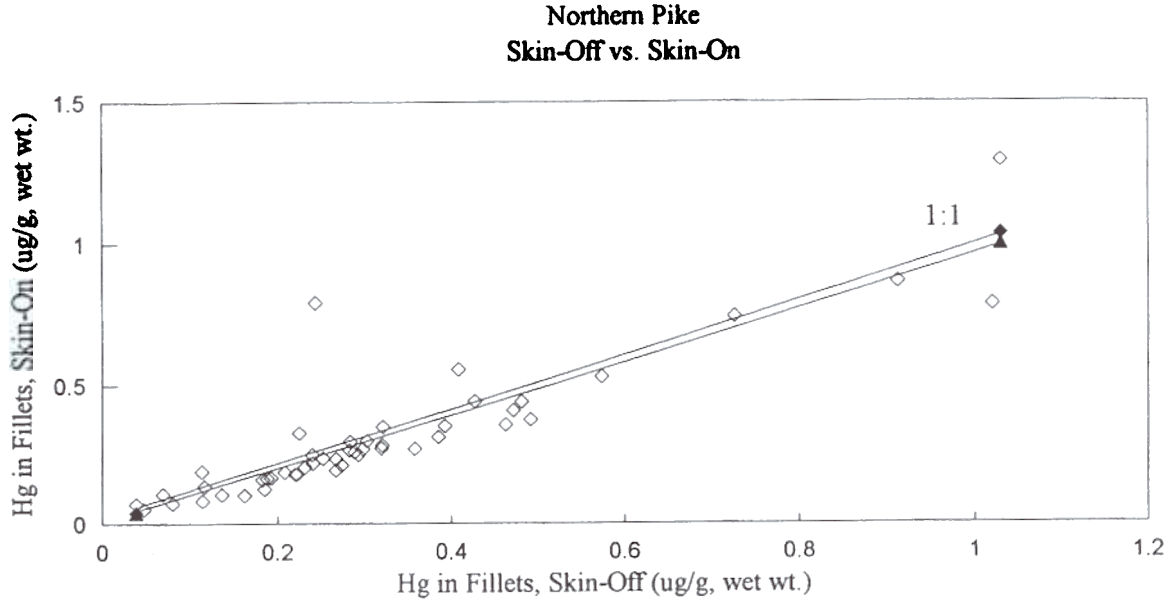
Fig. 6d. Pumpkinseed (y = 0.00091 x + 0.0090 r-squared = 0.16 P < 0.20 n = 10)



Soild symbols are not data points.

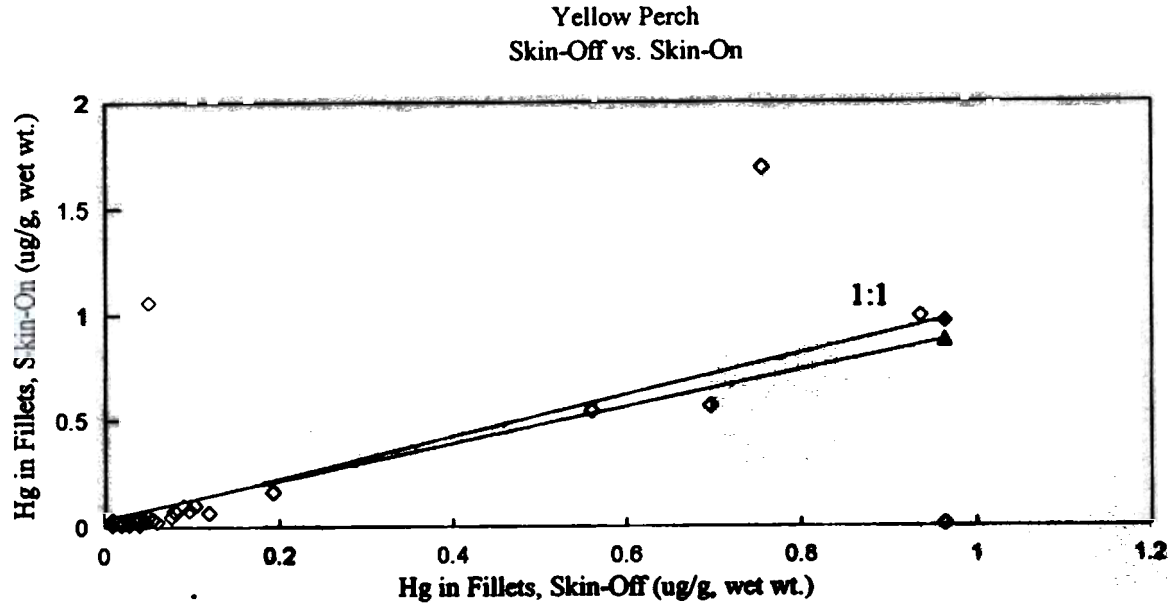
Figure 7. Relationship between Hg in Fillets, Skin-Off and Hg in Fillets, Skin-On (ug/g, wet wt.).

Fig. 7a. Northern Pike (y = 0.96 x + 0.0031 r-squared = 0.80 P > 0.001 n = 48)



Soild symbols are not data points.

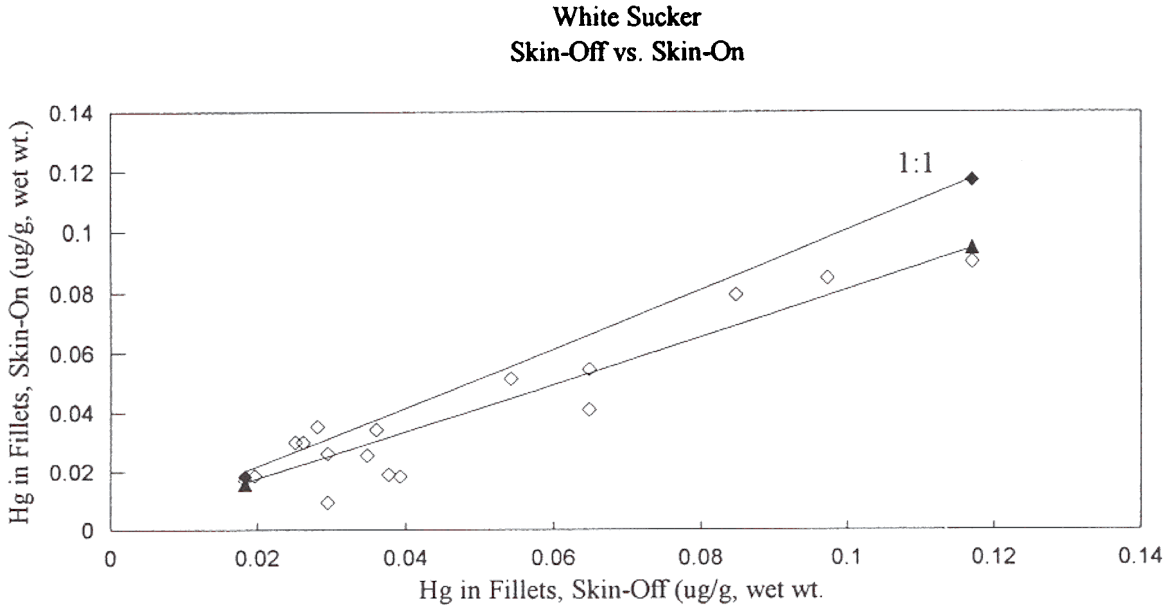
Fig. 7b. Yellow Perch (y = 0.89 x + 0.024 r-squared = 0.43 P < 0.001 n = 50)



Soild symbols are not data points.

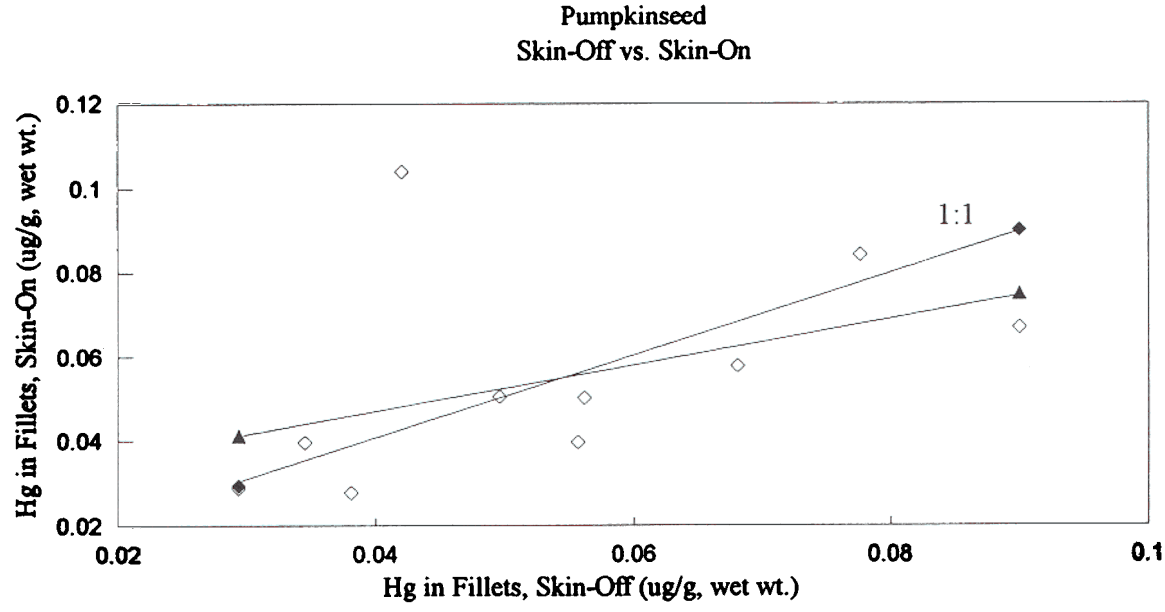
Figure 7. continued.

Fig. 7c. White Sucker (y = 0.80 x + 0.0011 r-squared = 0.87 P < 0.001 n = 17)



Soild symbols are not data points.

Fig. 7d. Pumpkinseed (y = 0.55 x + 0.025 r-squared = 0.20 P < 0.20 n = 10)



Soild symbols are not data points.